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STRUCTURAL AND DROPTEST ANALYSIS OF HELICOPTER LANDING SKIDS

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ABSTRACT

Landing skids of Helicopter are directly attached to the helicopter structure. These skids should be able to withstand buckling of struts, stresses &strains. So in the current study, we will consider a Composite material, High strength steel alloy, Aluminum alloy, for the structure and perform structural analysis and drop tests to study which material can perform satisfactorily under normal lending conditions. Helicopter skids are modeled based on the design of an Ultra Light Helicopter.

KEYWORDS: Landing Skids, Structural Analysis, Drop Test & Simulation of Drop Test

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Original Article

INTRODUCTION

Helicopter undercarriage skids, contain combined skids with a longitudinal support stretch for standing on ground associated that area unit connected to a front and rear cross-piece (Cross tubes) for attachment to structure of a craft by connecting devices. Winged aircraft traditionally use one of two types of landing gear systems. The oleo-strut landing gear with wheels offers advantages of initial taxi and take-off run capability, but at the cost of design complexity. Skid landing gears on the other hand offer simplicity in design and reduction in empty weight (WE). Currently skid landing gears are manufactured from metal alloys such as Aluminum, Steel, and Carbon fiber. The Elasto-plastic properties of such metals offer significant energy dissipation capabilities during plastic binding. FAR regulations permit yielding of the landing gear under limit load conditions. When subjected to crash masses, metal plastically deforms, riveting energy and permitting the body underbelly to crash in an exceedingly controlled crashworthy manner. The reduction in gross weight WG and empty weight we have a tendency to area unit 2 primary performance issues for a designer. Lightweight weight styles, corrosion resistance issues in metals, in addition, as fatigue performance are often adequately improved by victimization composites.

Skid-type landing gears (heavier than aircrafts per the state of the art) contribute significantly to the full air drag of a helicopter. Throughout quick forward flight of a heavier-than-air craft concerning 2 hundredth of the full air drag is contributed by the skid-type landing gears. A crucial quantity of fuel must be consumed throughout missions with a high cruising share to beat this air drag with this further quantity of fuel adding to the prices of the mission and Adding to the burden of the heavier-than-air craft so limiting the operational vary of the heavier-than-air craft. A skid-type undercarriage for a heavier than aircraft, significantly a light-weight and middle weight heavier-than-air craft, contains a minimum of 2 bows formed cross tube directed symmetrically

towards a left and right hand facet of a longitudinal axis of contains a minimum of 2 bows formed cross tubes directed symmetrically towards a left- and a Right-hand facet of a longitudinal axis of the heavier than aircraft at outboard ends

Composite structures have the capability of high strength to weight ratio and they also offer excellent in fatigue performance and do not have the same properties associated with corrosion which metals have. Cronkhite [8] has found that composite fuselage structures can be designed and fabricated for crashworthiness. Carbon Fiber Reinforced Polymer composites (CFRP) and honeycomb structures (NOMEX) have been used for the composite fuselage sections and at the same time using to outer protective shell. Fasanella [9] have used foam sandwiched in between the outer and inner composite shells for a fuselage with an external and internal composite shell and composite floor, all of these showing no damage in terms of sub-floor crushing but there is significant damage to the outer skin. Using composites further research going on crashworthy fuselage designs, for example, V22-Osprey tilt rotor aircraft, using composite materials industries are already starting their fuselage designs. Currently the Longbow helicopter uses an advanced metallic blade and has tested an advanced composite rotor blade. According to the Federal Aviation Regulation (FAR) Part 27.725 [10]: Especially the limit drop test must be conducted as follows: (a) The drop-in height must be in the range of (1) 13 inches from the lowest point of the landing gear to the ground [10]; or else (2) Any lesser height, which is not less than eight inches, resulting in a dropping contact velocity equal to the greatest probable sinking speed which is likely to occur at ground contact in normal power off landings. Mainly the composite skid landing gear will have the capability to produce load factors which are acceptable and also maintain structural integrity during limit drop tests. According to literatures Composite materials typically does not yield [8]. Hence, first ply failure and gross damage are of concern. The former should be manageable and the latter should not occur and the Multiple landing scenarios are of concern. However, Airoldi and Janszen and Tho [8] et al have shown that there are typically three landing scenarios, namely, level landing, level landing with drag (run-on) condition and rolled attitude landing, are mainly critical to limit load design. As per FAR Part 27 [10] under limit loads, metal alloy skid landing gears are permitted to yield. Finally, the last concern is crashworthiness. Fleming and Vizzini [9] concluded that those composite columns under off-axis loads greater than 10º do not exhibit favorable Specific Energy Absorption (SEA) [20]. That's why; the focus would need to be given to the cross member inclined beams, which are typically greater than 45º to the vertical.

For current project, I have considered the Landing skid design of Furia Helicopter which is an Ultra-light Helicopter which can be constructed at home with a construction kit and this entire helicopter is tested and certified as per FAR regulations and my goal in this project is to replace the existing landing gear with much lighter version so as to reduce total structural weight of the body and also to improve better overall performance when compared to Steel 4130 used currently on the landing skids.

Specifications of FURIA Helicopter

The specifications FURIA Helicopter have tabulated below

Table 2.1: Specifications of FURIA Helicopter [13]

Specification	Value (US units)	Value (SI Units)
Main rotor Diameter	19 ft	5791.2 mm
Tail rotor Diameter	3.6 ft	1097.28 mm
Height	6.9 ft	2103.12 mm
Length	12.5 ft	3810 mm
Max. Gross Weight	700 lbs	317515 g

Table 2.1: contd.,		
Empty Weight	325 lbs	147418 g
Payload (with full fuel)	350 lbs	158757 g
Fuel Capacity	8 gal	30.2833 liters
Seats	1	1
Range	80 m	128748000 mm
Takeoff Distance	0 ft	0 mm
Landing Distance	0 ft	0 mm
Vmax	95 mph	152.888 kph
VCr	70 mph	112.654 kph
Climb rate @ msl	1.100 ft/s	338.328 mm/sec
Service Ceiling	12.500 ft	3810 mm
Engine	Rotax 65 hp	

Drop Test Analysis

Drop test simulation creates a virtual environment to show what happens when a body strikes a surface, many electronic and mechanical devices has their own drop test methodology or criteria. It can be very useful to determine the structural integrity of the component. There are three Drop test simulation methodologies, they are: Response Spectrum, Implicit and Explicit analysis.

MATERIALS

Here in the consideration of this project we used high strength steel, aluminium, Titanium alloys, Carbon-Fiber Reinforced Plastic (CFRP) now let us see some properties of these materials

Table 2.1: Material Properties of Steel 4130

Property	Value (Metric system)
Density (ρ)	7850 kg/m3
Young"s Modulus (E)	205 Gpa
Bulk Modulus (K)	140 Gpa
Shear Modulus (G)	80 Gpa
Poisson"s Ratio (ν)	0.29

Table 2.2: Material Properties of Aluminium 7075-T6

Property	Value (Metric system)
Density (ρ)	2810 kg/m3
Young"s Modulus (E)	71.7 Gpa
Bulk Modulus (K)	70.29 Gpa
Shear Modulus (G)	26.9 Gpa
Poisson"s Ratio (ν)	0.33

Table 2.3: Material properties of Ti-6Al-4V

Property	Value (Metric system)
Density (ρ)	4430 kg/m3
Young"s Modulus (E)	113.8 Gpa
Bulk Modulus (K)	120.04 Gpa
Table 2.3: contd.,	
Shear Modulus (G)	44 Gpa
Poisson"s Ratio (ν)	0.342

Table 2.4: Material properties of SF CFRP

Property	Value (Metric System)
Density (ρ)	1600 kg/m3
Young‟s Modulus (E1) at 00	70 Gpa
Young‟s Modulus (E2) at 900	70 Gpa
In Plane Shear Modulus (G12)	5 Gpa
Major Poisson‟s Ratio (ν12)	0.10

LANDING SKID'S DESIGN

CATIAV5 software is used to design landing skids of the helicopter with its detailed Components. The facilities provided by this software help to design fancy surfaces and irregularly shaped parts, and fix the possible interferences that may occur during the assembly of these parts to avoid any future problems. The major steps include

- Firstly, constructing a circle with dimension of 40 mm diameter and now changing the work bench to product design adopt for extrude option and get extrude up to 1750 mm. Secondly, getting a 3-d plane at a distance of 1500mm. Similarly draw the same circle and now we can get the same rod at a distance of 1500mm as shown in below Figure. 3.1.
- Now take a 3-d plane and go to the sketcher now draw the supporting struts diagram using it. After that, take **RIB** option and get extrude the strut assembly similarly draw the strut at some distance prescribed in the given geometry forming Cross tube shown below Figure. 3.2.
- Now by using the mirror option and also fillet, I have removed the sharp corners and completed the design process of FURIA helicopter landing skids.

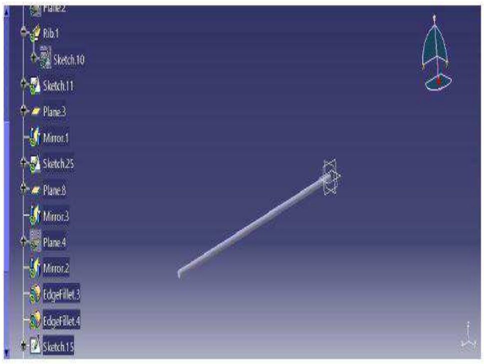

Figure 3.1: Designing Skid Tubes

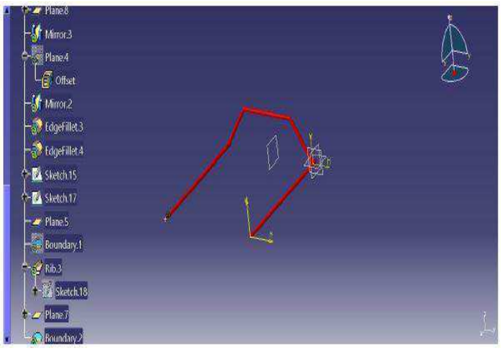

Figure 3.2 Designing Cross tubes

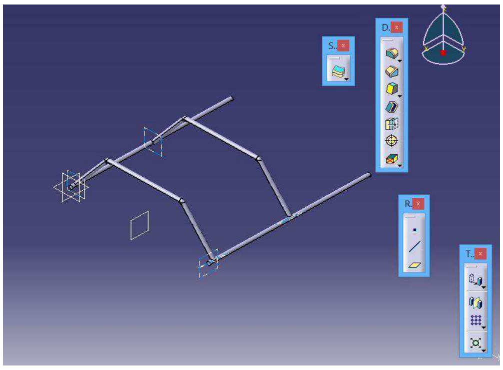

Figure 3.3: Completed Landing Skids

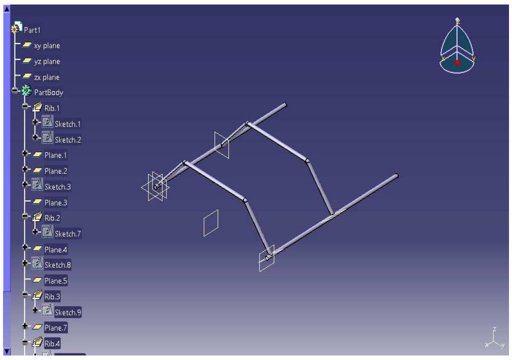

Figure 3.4: Isometric View of Landing Skids

STRUCTURAL ANALYSIS

From Table 4.1, we can clearly see that maximum gross weight of the Furia helicopter as 317.515 kgs and we also have designed the landing skid of the same using the same design. Since we know the actual dimensions and also have the data on the material properties we can now assume that an approximation of the total weight of the landing skid can be made.

Table 4.1: Approximation of Landing Skid Volume

Sections	Units	Volume (each) (mm3)	Complete Volume (mm3)
Cross tubes	2	2423200.044	4846400.088
Skid tubes	2	2253625	4507250
Total			9353650.088

Generally, this skid tube is made of Steel 4130 material its material properties are defined in Table 3.2 and also in this project we are using three other materials for analysis they are Aluminium 7075-T6, Ti-6Al-4V, Carbon fibre reinforced plastic their material properties can also be found in Table 3.3 for 3.5. Now using the values of density from material properties and volume of landing skid from our approximate calculations, we can now create rough estimate of weight for each landing skid with different material. Form below table, we can see that the total weight of landing skid is only 15kg‟s when we are using CFRP material and when using current material it is more than 73.4 kg.

Table 4.2 Weight estimates of landing skids

Sl. No	Material	Density (kg/mm3)	Volume (mm3)	Weight (kg)
1	Steel 4120	7.85E-06	9353650.088	7.34E+01
2	Aluminum 7075-T6	2.81E-06	9353650.088	2.63E+01
3	Ti-6Al-4V	4.43E-06	9353650.088	4.14E+01
4	CFRP (Standard Fibre)	1.60E-06	9353650.088	1.50E+01

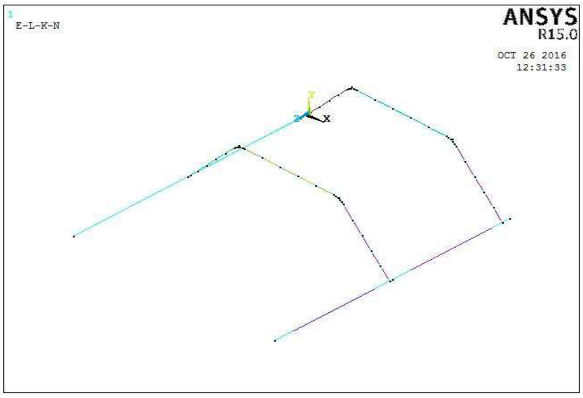

Figure 4.1: Meshed Landing Skid

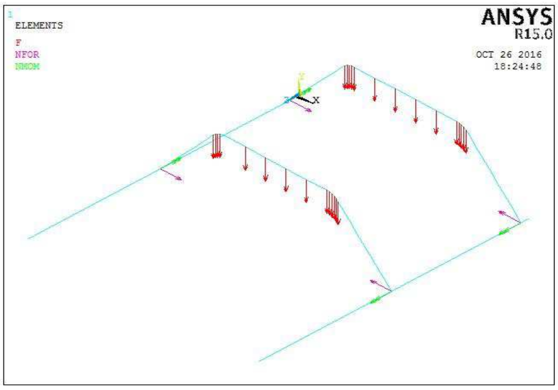

Figure 4.2: Structural and Displacement Load Data

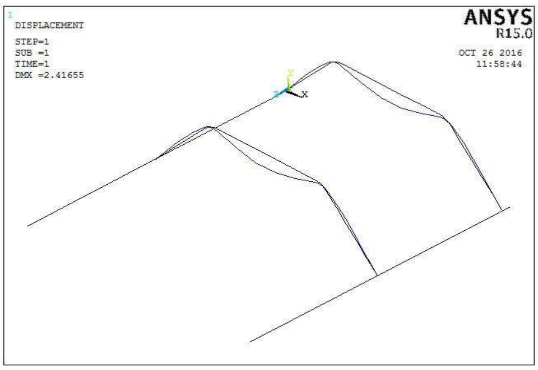

Figure 4.3: Maximum Deformation for Steel 4130

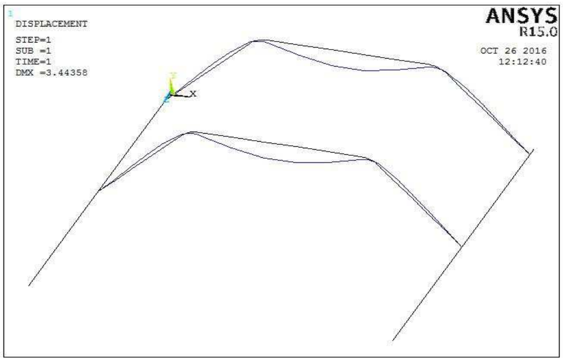

Figure 4.4: Maximum Deformation for Aluminum 7075-T6

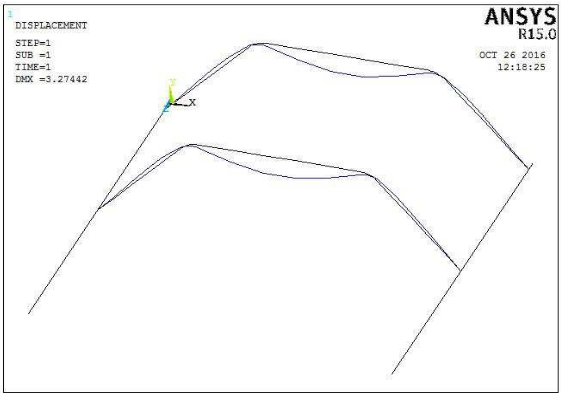

Figure 4.5: Maximum Deformation for Ti-6Al-4V

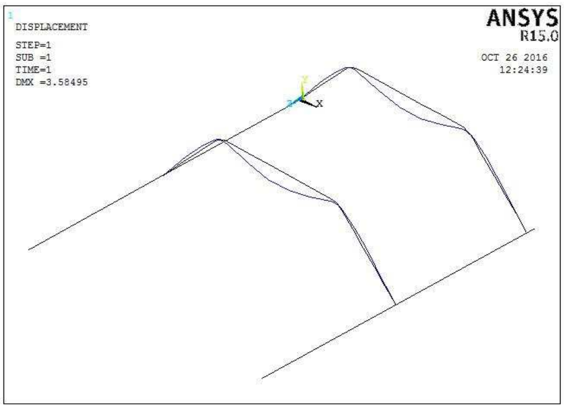

Figure 4.6: Maximum Deformation for CFRP

Table 4.3: Results Comparison

Pointer/ Material	Steel 4130	Ti-6Al-4V	Aluminium 7075-T6	CFRP (SF)
Maximum Deflection	2.41655	3.27442	3.44358	3.58495
X-component of displacement	0.36166	0.490057 to -0.490057	0.515374	0.536532 to -0.536532
Y-component of displacement	0.278515 to -2.41654	0.377388 to -3.27441	0.396885 to -3.44357	0.413178 to -3.58495
Z-component of displacement	0.118E-10	0.160E-10	0.169E-10	0.175E-10
Displacement Vector sum	2.41655	3.27442	3.44358	3.58495

DROP TEST SIMULATION

Drop tests are an important research tool in structural analysis and it is generally done under FAR 27 regulations [10]. The test considerations are as follows

Table 5.1: Drop Test Criteria

Test feature	Value
Drop height	330.2 mm
Drop speed	338.23 mm/s
Acceleration due to gravity	9810 mm/s2

To perform drop test analysis the complete design of the model and its finite element meshed model shown in below Figure.5.2 and Figure. 5.3

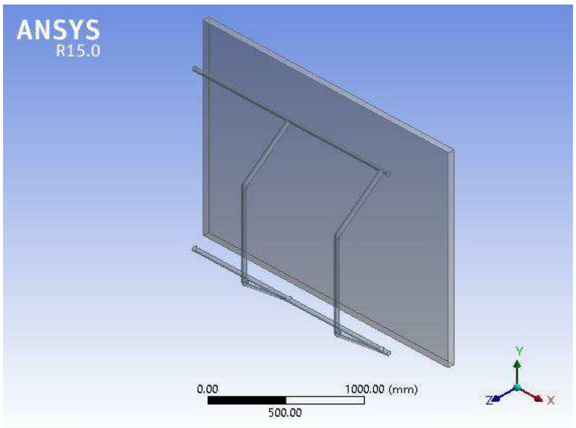

Figure 5.2: Explicit Dynamic Design Modeler

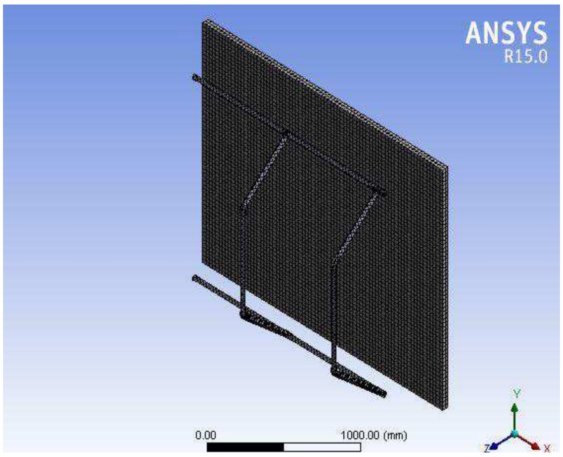

Figure 5.3: Explicit Dynamic FE Model

The entire setup is now completed and before starting the solution run up. The entire setup looks like below Figure. 5.4

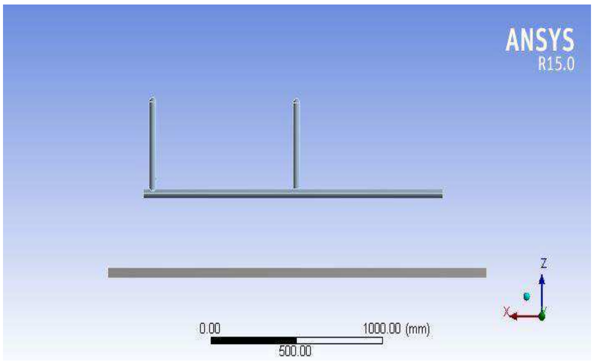

Figure 5.4: Drop Test Setup

Drop Test Simulation Results

The Drop test simulation results have been shown in below Figures for all four different materials.

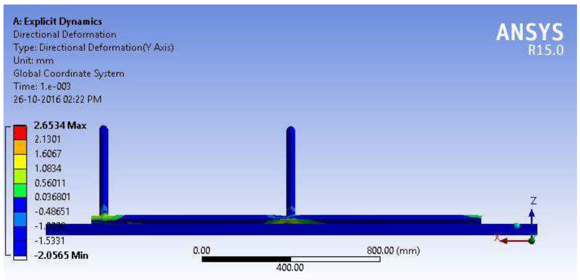

Figure 5.5: Drop Test for Steel 4130

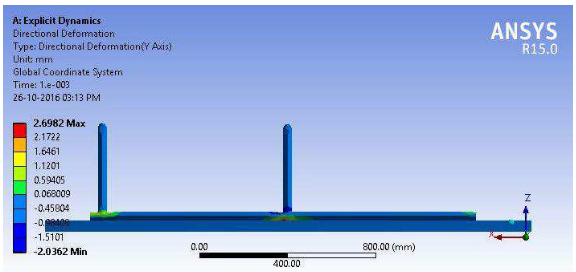

Figure 5.6: Drop Test for Aluminium 7075-T6

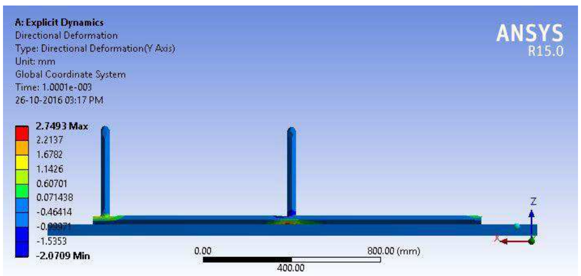

Figure 5.7: Drop Test for Ti-6Al-4V

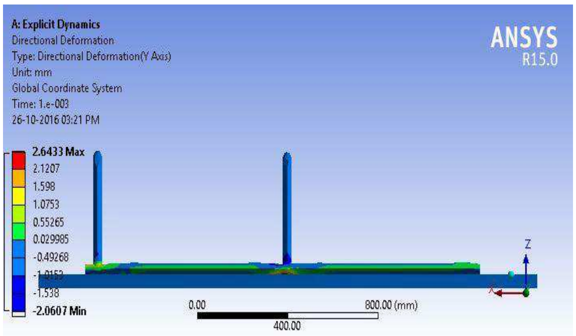

Figure 5.8: Drop Test for CFRP (SF)

Now let us tabulate the results of the drop test simulations from all four test cases.

Table 5.2: Drop Test Results

Material	Displacement (Max)	Displacement (Min)
Steel 4130	2.6534	-2.0565
Aluminium 7075-T6	2.6982	-2.0362
Ti-6Al-4V	2.7493	-2.0709
CFRP (SF)	2.6433	-2.0607

From above Table we can clearly see that above all the materials the drop test show similar displacement results over the spectrum.

- But if we can clearly concentrate on the pictures we can see there is slight physical deformation along the skids once the skid contacts the floor.
- For steel, which is generally preferred and used in the fabrication of skid we can see that there is no visible deformation, but the displacement is localized to welded joints.
- For Aluminium we have seen the same behaviour akin to that of Steel 4130 making one of good alternative the displacement is also localized to welded joints.
- For Titanium we saw that skid showed little physical distortion and high displacement value, but the cost and feasibility machining under conventional techniques makes it difficult to adopt it fabrication of this landing skid.
- Finally, CFRP has shown the lowest displacement value, but it has significant distribution of load along its span. Though this skid has saved a lot of weight and performed well under structural loading. It has not acted up to mark in Drop test.
- So we can go on and replace the landing skid material of steel 4130 with Aluminium 7075-T6 as it offers better weight saving and good structural strength and also behave closer to the original design in the drop test scenario.

CONCLUSIONS

We have seen the behaviour of the helicopter landing skids of FURIA helicopter with four different materials and under two separate test conditions

- The first test is the structural analysis where we have calculated the weights of landing skids with different materials and subtracted it from the total gross weight. Applying that weight onto respective landing skids to see

its response,

- From there we can see that Steel shows very low deflection upon taking the total weight of body on itself.
- Now, Drop test following FAR27 Regulations we have seen that both CFRP and Aluminium alloy has shown a similar response to drop test methodology so we can say that replacing Steel with either Aluminium and CFRP in the near future can not only decrease the total weight of the landing structure but also improve the performance under limit load conditions.
- Now the weight of the landing skids with steel material is around 73 kg and it drops to only 26 kg when we use aluminium and 14 kg in the case of CFRP, this greatly reduces total gross weight of the landing skid.

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